THE EFFECT OF COOKING AND STORAGE ON THE ASCORBIC ACID CONTENT OF POTATOES

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INTRODUCTION

Potatoes are consumed throughout a period beginning before their maturity and extending from 5 to 10 months after the tubers are harvested. During this period they undergo metabolic changes, the character and extent of which depend upon the duration and conditions of storage as well as upon the variety of potato. These changes are accompanied by changes in the ascorbic acid content. Since potatoes are never or rarely eaten raw, the effects of the numerous methods of cooking must also be considered if a true picture of their antiscorbutic value is to be obtained.

Although chemical methods of analysis simplify the quantitative determination of ascorbic acid, the application of these methods to biological material frequently creates new difficulties in the interpretation of results. Furthermore, in the case of the potato, insufficient information with regard to one or more of the common variables, time and temperature of storage, variety of potato, and cooking method, adds greatly to the difficulty of making a satisfactory comparison between the results of different investigators. Although the ascorbic acid content of raw potatoes is reported to vary between the wide limits of 53 mg. per 100 gm. (10) and 1.5 mg. per 100 gm. (13), the results of most investigations indicate that newly harvested potatoes are highest in vitamin C value and that this quantity diminishes very rapidly during the first part of storage and later more gradually (16, 18, 22, 26). Kröner and Steinhoff (8) noted this decrease followed by a rise during the latter part of storage, and Pett (18) reported that sprouting caused an increase followed by a rapid decrease.

Fixsen (4) has summarized the data that show the effects of cooking upon the ascorbic acid content of potatoes. No general agreement exists. The same method of preparation reported by some investigators as causing a loss in ascorbic acid value, has been reported by others as apparently causing a gain; and one investigator reports that the same method of cooking results in a loss of ascorbic acid in one variety and a gain in another. Richardson, Davis, and Mayfield (20) reported a gain of 28 to 75 percent in ascorbic acid as a result of baking potatoes, whereas Lyons and Fellers (12) using the same method of cooking noted a loss of 50 percent. The gain in ascorbic acid found after cooking has been ascribed variously to the presence in the raw tuber of a protein-ascorbic acid ester capable of hydrolysis on cooking.
(9, 13, 16, 19, 23), to the destruction of the ascorbic acid oxidase by heat (3, 14), and to the increased permeability of cooked tissue to the extracting medium, which results in greater ease of extraction of the vitamin from cooked than from raw potatoes (16, 25). It is hoped that the present investigation may point to definite conclusions on some of these controversial issues.

MATERIALS AND METHODS

SOURCE AND TREATMENT OF EXPERIMENTAL POTATOES

The Irish Cobbler and Green Mountain potatoes used in the major part of this study were furnished by the Bureau of Plant Industry and were grown at Aroostook Farm, Presque Isle, Maine. They were received on October 24, 1938, and placed in storage at 15.5° C. with a relative humidity of 80 percent. Six weeks later, half of the potatoes of each variety were removed to another storage room kept at 4.5° and a relative humidity of 80 percent. Sprouting was arrested at the storage temperature of 4.5° but continued in the potatoes stored at 15.5°. After a total of 4 months of storage, all sprouts were removed from the latter group. Any sprouts present were always removed at the time a potato was analyzed for ascorbic acid content.

The Irish Cobbler potatoes stored at 15.5° C. were used in a study of the effect of pressure cooking, baking, boiling (pared and unpared), and steaming (unpared) upon the ascorbic acid content of potatoes. For comparison, raw potatoes were analyzed simultaneously with potatoes cooked by each of these methods. These analyses of raw tubers, performed at intervals during the storage period, gave a history of the effect of storage at 15.5° upon the ascorbic acid content of Irish Cobbler potatoes. In addition determinations were carried out at intervals on the raw Green Mountain potatoes stored at 15.5° and on both varieties stored at 4.5°.

Since it was also desired to determine the effect of the so-called "waterless" cooking method upon the vitamin C value of potatoes, and there were not enough of the Maine-grown potatoes left in good condition, this part of the experiment was carried out on "new" Green Mountain potatoes obtained on the local market. Analyses were made of boiled pared potatoes and of pared potatoes cooked by the waterless method. Comparison was also made with raw potatoes simultaneously analyzed.

Summer Chippewa potatoes grown by the Bureau of Plant Industry at the experimental farm at Beltsville, Md., were made available for a study of the effect of maturity on the ascorbic acid content of potatoes. The analyses were begun 82 days after planting when the skins were still "feathery" and were made on the maturing tubers at semiweekly intervals for 6 weeks, by which time the vines were dead. The potatoes were delivered to the laboratory on the same day they were harvested and analyses were completed within 2 days. A disease, fusarium wilt, which ultimately became apparent in over half of these potatoes, developed at about the middle of the experimental period. Only tubers which appeared to be unaffected were analyzed. The effect of storage at 25.5° C. was also investigated.
SAMPLING PROCEDURE AND CHEMICAL METHODS

In the analysis of potatoes for their ascorbic acid content, the problem of representative sampling has often been overlooked or ignored. In the case of raw potatoes, grating or slicing and mixing, preliminary to sampling increases the possibility of formation of dehydroascorbic acid and of irreversibly oxidized ascorbic acid. However, unless the distribution of ascorbic acid is uniform throughout the tuber, there can be no assurance that a small single sample from a tuber is representative of the whole.

Preliminary experiments indicated that the distribution of ascorbic acid was not uniform throughout the tuber. All of the Maine-grown potatoes were sampled by the following method: Four wedge-shaped sections, weighing between 12 and 20 gm., were cut from the center to the outer edge from each potato. One of these sections was cut from the stem end, another from the bud end, and one from each side. The small size of many of the Chippewa potatoes made it possible to analyze entire tubers as one sample, and the larger potatoes of this group and of the Green Mountain potatoes bought on the local market were of such size that they could, in most cases, be represented accurately by two samples instead of four. When fewer than four samples were cut from a potato, care was taken that the wedges selected for analysis should represent both the stem and bud end of the tuber.

The ascorbic acid in raw potatoes was extracted by grinding each sample with 12 gm. of acid-washed sand under three successive portions (20 to 30 ml. each) of an aqueous solution containing 8 percent of acetic and 2 of metaphosphoric acid (6, 11, 14, 15). The three extracts, separated from the pulp by centrifugation, were combined and made up to 100 ml. Two 25-ml. aliquots of each were titrated with 2-6-dichlorophenol-indophenol according to the method of Tillmans, Hirsch, and Hirsch (24) as modified by Bessey and King (2). All reagents were made up with glass-distilled water and all glassware was rinsed with glass-distilled water before use.

The average of the ascorbic acid content of all the samples of a single potato was taken as its ascorbic acid value and from 5 to 10 potatoes were used in each series of determinations. The analyses of raw potatoes were made on pared tubers whenever paring was introduced preliminary to the cooking method; in all other cases analyses were on unpared tubers.

Cooking causes a gelatinization of the starch in potatoes, and after the cooked tissue is ground with acid and sand, centrifugation yields a very cloudy suspension. It was found, however, that breaking up the potato tissue with a stirring rod and mixing it thoroughly with the acid resulted in the removal of essentially the same percentage of the total ascorbic acid with each extraction as when grinding with sand was employed (table 1). Also the resulting extracts were clearer and the end points at titration easier to distinguish. Only a fraction of the total ascorbic acid was removed by each extraction, and further experiments showed that with the weight of sample and size of centrifuge tube (50 ml.) used, 12 washings were necessary to remove all of the ascorbic acid from cooked potato tissue. However, six extractions constantly removed very close to 90 percent of the ascorbic acid present and at the same time the volume could be confined to 100 ml. As shown in table 1, this difficulty of removal of ascorbic acid was not encountered when raw potatoes were analyzed.
### Table 1.—Extraction of ascorbic acid from raw and cooked potato tissue

<table>
<thead>
<tr>
<th>Extractions (number)</th>
<th>Proportion of total ascorbic acid removed at end of each extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cooked tubers,¹ samples—</td>
</tr>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1</td>
<td>24.2</td>
</tr>
<tr>
<td>2</td>
<td>49.3</td>
</tr>
<tr>
<td>3</td>
<td>65.6</td>
</tr>
<tr>
<td>4</td>
<td>76.3</td>
</tr>
<tr>
<td>5</td>
<td>83.1</td>
</tr>
<tr>
<td>6</td>
<td>90.5</td>
</tr>
<tr>
<td>7</td>
<td>94.0</td>
</tr>
<tr>
<td>8</td>
<td>97.2</td>
</tr>
<tr>
<td>9</td>
<td>100.0</td>
</tr>
</tbody>
</table>

¹ Samples A and B were ground with sand in the second, third, and fourth extractions. The remaining extractions of these samples and all extractions of samples C and D were made without sand as described in the text.

² The titration value for the ninth extraction was so small that for practical purposes 100-percent extraction was assumed.

The following procedure was employed in the analysis of cooked potatoes: Centrifuge tubes containing about 20-ml. portions of the extracting medium were weighed and chilled in an ice bath. Four wedge-shaped samples were taken as soon as possible after the potatoes were cooked and each sample was cut immediately into small pieces and dropped into the cold acid. The tubes were then reweighed to determine the weight of the sample. Extraction was carried out with six successive portions of the mixture of acids, the potato tissue being thoroughly broken up and mixed with each fresh portion of acid. Centrifugation for 4 minutes at high speed gave a fairly clean separation of liquid and solid. The combined extracts were made up to 100 ml. and two aliquots of each sample were titrated.

In consideration of the results presented in table 1, the values for ascorbic acid so obtained were taken to be 90 percent of that present in the samples and the total amount was accordingly estimated on this basis. Finally, taking into account the loss or gain in weight on cooking, the values were readjusted to the basis of the raw weight of the potato.

**COMBINED ASCORBIC ACID**

McHenry and Graham (13) and others have reported the presence of a protein ester or "bound" ascorbic acid in potatoes. This compound is said to be soluble in water and insoluble in the ordinary ascorbic acid extractants, but capable of hydrolysis on heating or on treatment with 1 percent hydrochloric acid to free the soluble ascorbic acid.

Since both Green Mountain and Irish Cobbler potatoes are reported (19) to contain large quantities of this ester, various attempts were made to determine its presence. The residues remaining after the usual acid extraction of the raw potato tissue were treated with 1 percent hydrochloric acid according to Reedman and McHenry's directions (19). Several variations in time and temperature were used. In no case was there any additional titration value as a result of this treatment. The residue remaining after thorough extraction
of the potato tissue with trichloroacetic acid—a better protein precipitant than the acetic-metaphosphoric acid mixture—gave the same negative reaction to hydrolysis. This agrees with the results reported by Bessey (1) of similar experiments on Green Mountain and Irish Cobbler potatoes. Fujita and Ebihara (5) have reported recently that there are some grounds for believing the ascorbic acid in plant tissue to be partially bound to protein. They state, however, that this "bound" ascorbic acid is readily converted to the free form in the presence of metaphosphoric acid and is thus completely removed from the tissue by ordinary extraction procedure.

**DEHYDROASCORBIC ACID**

At various times during the course of the experiment, portions of the extract were treated with hydrogen sulfide for 20 to 30 minutes as a first step toward determining whether any dehydroascorbic acid was present. No increased reducing activity could be determined except in one case. Then it was not certain that all of the hydrogen sulfide had been removed. Bessey (1) found a small amount of dehydroascorbic acid in both Green Mountain and Irish Cobbler potatoes after storage. He recommends longer contact with hydrogen sulfide in a slightly less acid medium, which may account for the difference in his results.

**EFFECT OF METHOD OF COOKING ON ASCORBIC ACID CONTENT OF POTATOES**

In order that the potatoes cooked by different methods should attain the same stage of "doneness," cooking was discontinued when the internal temperature measured at the center of the tuber had reached 96° C. In each individual cooking, potatoes of approximately the same weight were used. A thermometer was inserted with the bulb at the center of one potato (two in baking) of each lot, with the exception of those prepared in the pressure saucepan and by "waterless" cooking. In the latter instances, the time required to bring a given weight of potato to the required temperature was determined by preliminary experiment, and this time was adhered to in the remainder of the tests. Potatoes without thermometers from each cooking lot were used for analysis. In the study of any given cooking method the tubers analyzed raw were of the same weight as those which were analyzed after cooking. The results of these analyses are given in table 2 in which the data showing the effect of each method of cooking upon the ascorbic acid content of potatoes are summarized.

**BAKING**

Three or four unpared Irish Cobbler potatoes weighing between 200 and 250 gm. were prepared in an oven maintained at a temperature of 215° C. The time required varied from 47 to 52 minutes. The potatoes lost 15 to 17 percent in weight and the average loss of ascorbic acid, calculated on the basis of raw weight, was 15 percent.

**STEAMING**

Three unpared Irish Cobbler potatoes weighing between 153 and 180 gm. were used for each cooking. They were cooked in a covered
steamer over 4 quarts of rapidly boiling water. This method required from 33 to 39 minutes except in one case when the time extended to almost 51 minutes. There was usually a gain in weight on the order of 1 gm. per potato. No ascorbic acid was recovered in the water. About 10 percent of the ascorbic acid originally present in the raw potatoes was destroyed.

### Table 2. Ascorbic Acid Losses in Cooking Irish Cobbler and Green Mountain Potatoes

| Variety and cooking method | Raw potatoes | | | | Cooked potatoes | | | | | | Ascorbic acid recovery in | | | | | | | | | |
|---------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                           | Tubers       | Number      | Milligrams  | Tubers       | Number      | Milligrams  | Milligrams  | Percent     | Percent     | Percent     | Percent     |             |             |             |             |             |             |             |
| Irish Cobbler, stored:    |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| Baked                     | 5           | 10.6±0.21   | 5           | 9.6±0.30    | 85          |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| Steamed, unpared          | 10          | 10.1±0.19   | 8           | 9.1±0.14    | 90          |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| Steamed in pressure       |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| cooker, pared             | 6           | 9.7±0.15    | 6           | 8.2±0.21    | 85          |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| Boiled, pared             | 8           | 10.5±0.12   | 8           | 7.8±0.20    | 75          |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| Green Mountain, "new":    |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| Boiled, pared             | 10          | 20.0±1.34   | 10          | 16.1±0.92   | 80          |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| "Waterless" cooking, pared| 10          | 17.3±0.73   | 11          | 15.8±0.47   | 91          |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |

1 The figures following the symbol ± represent the standard errors of the mean.
2 The extent of destruction of ascorbic acid is not statistically significant.

### Boiling

The potatoes were cooked by immersion in boiling, distilled water. The volume of liquid required to keep the potatoes completely covered in a 3-quart saucepan (7 inches in diameter) throughout the cooking period was calculated from the formula:

\[
\text{Total weight of potatoes} \times 2.5 - 200 = \text{milliliters of water required.}
\]

Potatoes were boiled pared and unpared. Three potatoes weighing between 140 and 180 gm. were used in each case. The unpared potatoes (Irish Cobbler) required from 33 to 40 minutes cooking time and gained about 1 gm. apiece in weight. They lost about 10 percent of their original content of ascorbic acid, none of which was found in the cooking liquid.

The pared potatoes required from 31 to 37 minutes for cooking. The Irish Cobbler potatoes gained from 2 to 6 gm. in weight and there was very little sloughing. The potatoes contained 76 percent of their original ascorbic acid and an additional 5 percent was recovered in the cooking liquid so that the destruction of the vitamin was 19 percent.

The "new" Green Mountain potatoes were more mealy than the Irish Cobbler, which had been stored, and there was a great deal more sloughing during cooking. Nevertheless these potatoes retained 80 percent of their ascorbic acid value. The cooking liquid contained another 12 percent. The average destruction of ascorbic acid in these potatoes was 8 percent, but because of the magnitude of the
standard error, this difference cannot be regarded as significant. If the ascorbic acid present in the cooking liquid were disregarded the loss would be 24 percent in the Irish Cobbler and 20 percent in the Green Mountain potatoes.

PRESSURE COOKING

For the pressure-cooking experiment a 3-quart pressure cooker made of cast aluminum was used. The cover, which was automatically steamtight, contained a vent pipe to which a weight was fitted so that pressure could be maintained at 15 pounds. It was possible to cool the whole cooker very rapidly by placing it in a pan of cold water so that cooking was stopped almost instantly when the utensil was removed from the flame.

Two Irish Cobbler potatoes weighing between 100 and 114 gm. were cooked at one time. They were placed on a rack in the cooker and one-fourth cup of hot water was added. Two minutes were required for the pressure to reach 15 pounds and it was maintained at this point for 15 minutes, giving a total cooking time of 17 minutes. The pressure was released in 10 to 15 seconds.

The gain in weight for different samples of potatoes varied from zero to 4.5 gm. They retained on an average 85 percent of their ascorbic acid value and an additional 4 percent was recovered in the small amount of liquid remaining at the end of the cooking period, so that the destruction of vitamin C was 11 percent, with a loss of 15 percent if this liquid was discarded.

"WATERLESS" COOKING

Four "new" Green Mountain potatoes weighing between 95 and 135 gm. were prepared at one time in a 1½-quart, heavy aluminum, covered pan. They were washed after paring, placed in the pan, rinsed in cold water, and the water poured off so that the potatoes remained moist. During the first half of the cooking period the temperature inside the pan was maintained slightly below the boiling point so that the formation of vapor was slow and its escape from the container not apparent. Thereafter the temperature was lowered and for the remainder of the cooking period it was maintained at 84° to 86° C. An indicator in the cover of the pan made control possible. The total cooking period was 64 minutes. At the end of cooking there was no remaining liquid, the potatoes were very lightly browned at the points of contact with the pan, and there was a slight skin formation. They lost from 3 to 5 gm. apiece in weight and an average of 9 percent of their ascorbic acid content. In view of the magnitude of the standard error, this loss of ascorbic acid cannot be regarded as significant.

RELATION OF DEGREE OF MATURITY OF POTATOES TO ASCORBIC ACID CONTENT

The Chippewa potatoes analyzed semiweekly for 6 weeks prior to maturity decreased in ascorbic acid content during that period from 25.5 to 20.1 mg. per 100 gm. (table 3). The ascorbic acid content of the potatoes did not change between the twelfth and fourteenth week after planting. At the end of the fourteenth week a decrease in
ascorbic acid occurred simultaneously with the appearance of a diseased condition in the tubers. For this reason, although only apparently healthy tubers were analyzed, it is uncertain whether or not the decrease in ascorbic acid value is attributable to the maturity of the vines. Lyons and Fellers (12) found no loss of ascorbic acid in maturing Green Mountain potatoes.

There was a wide variation in the size of the potatoes throughout the entire experimental period. Tubers ranging in weight between 12 and 193 gm. were analyzed. As far as possible, the entire size range was represented in each lot of potatoes analyzed and no relationship was found between the concentration of ascorbic acid present and the weight of the tuber.

Table 3.—The ascorbic acid content of maturing Chippewa potatoes per 100 gm. of tuber and effect thereon of short periods of storage

<table>
<thead>
<tr>
<th>Period after planting (weeks)</th>
<th>Without storage 1</th>
<th>Stored at 25.5° C. for 1—</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tubers examined</td>
<td>Ascorbic acid content</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Milligrams</td>
<td>Tubers examined</td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>26.4±0.74</td>
<td>25.9±0.78</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>26.4±1.15</td>
<td>25.9±1.05</td>
</tr>
<tr>
<td>14</td>
<td>13</td>
<td>25.9±1.05</td>
<td>20.6±0.47</td>
</tr>
<tr>
<td>15*</td>
<td>10</td>
<td>22.2±1.01</td>
<td>19.2±1.50</td>
</tr>
<tr>
<td>16</td>
<td>13</td>
<td>23.2±0.85</td>
<td>18.7±1.05</td>
</tr>
<tr>
<td>17*</td>
<td>14</td>
<td>20.1±0.69</td>
<td>16.7±1.05</td>
</tr>
</tbody>
</table>

1 Figures following the ± symbol show the standard error.
2 Fusarium wilt was well developed.
3 The vines were dead at this time.

EFFECT OF STORAGE ON ASCORBIC ACID CONTENT OF POTATOES

Olliver (16) reported a loss of 50 percent of the ascorbic acid from new potatoes after 15 days of storage and Pett (18) a loss of over 50 percent after 20 to 30 days. In the present study there was also a marked decrease in the ascorbic acid content of stored potatoes, very rapid during the first few weeks after harvesting, and more gradual thereafter. The immature Chippewa potatoes lost 22 percent of their ascorbic acid after 1 week’s storage at 25.5° C. and 36 percent in 3 weeks (table 3).

"New" Green Mountain potatoes bought on the market decreased in ascorbic acid content from 20.0 to 17.3 mg. per 100 gm., a loss of 14 percent in about 10 days at 25.5° C. These potatoes had probably been harvested for at least a week before the first analysis for ascorbic acid was made.

The Maine-grown Green Mountain potatoes lost about 30 percent of their ascorbic acid in the first month of storage at 15.5° C. (fig. 1). Unfortunately no figures were obtained for the Irish Cobbler potatoes during the first period of storage, but the close agreement of the curve with that of the Green Mountain potatoes for the remainder of the 15.5° storage period suggests the probability of similar behavior at the beginning. Green Mountain potatoes stored at 15.5° for 5
months had an ascorbic acid content of 10.1 mg. per 100 gm., a loss of nearly 50 percent of their original value. Irish Cobblers stored for the same period and at the same temperature contained 9.9 mg. per 100 gm.

It is interesting to note that in these potatoes the rate of loss of ascorbic acid at 15.5° and 25.5° C. was apparently independent of the variety of the potato, but dependent, to some extent at least,

![Graph showing ascorbic acid content over storage period](image)

**Figure 1.**—Ascorbic acid content of Irish Cobbler and Green Mountain potatoes during storage at 15.5° and 4.5° C.

upon the ascorbic acid content of the tuber. The variation in ascorbic acid content from tuber to tuber was much smaller in potatoes that had been stored for a short period than in immature and new potatoes. This approach to uniformity during storage could only have been brought about if the loss of the vitamin were greater during the same period from tubers of high ascorbic acid content than from those of lower ascorbic acid content.
When Irish Cobbler and Green Mountain potatoes were placed in storage at 4.5° C. after a preliminary period of 6 weeks at 15.5° the loss of ascorbic acid was more rapid in both varieties as compared with the loss at 15.5°. At the end of the storage period (25 weeks) the ascorbic acid content of the Green Mountain potatoes had dropped to 7.5 mg. per 100 gm. and that of the Irish Cobblers to 5.9 mg. per 100 gm. Apparently the interference with the physiological processes caused by lowering the temperature has a marked effect upon ascorbic acid.

From these results it would seem that the storage of potatoes in cellars where the temperature approaches the freezing point during the winter would cause a greater loss of ascorbic acid than storage in warmer cellars. However, Kröner and Steinhoff (8), who kept potatoes in such a storehouse, found that the ascorbic acid content reached a low value and then increased steadily during the spring, following the rise in the temperature of their storehouse.

In view of the increase noted by these authors and of the data presented here, it seems possible that the detrimental effects of storage at a low temperature upon the ascorbic acid content of potatoes might be offset to some extent by later storage at a higher temperature.

**DISTRIBUTION OF ASCORBIC ACID IN THE POTATO TUBER**

It has been repeatedly stated (7, 12, 17) and apparently is usually assumed that the distribution of ascorbic acid in the raw potato is uniform or nearly so, although Rudra (21) found a higher concentration in the skin than in the flesh of new potatoes. Some of the potatoes used in the present study were examined after a period of storage, and it was found that, although there was a tendency for the concentration to be higher in the cortical layer, the difference between it and the medullary layer was slight.

When wedge-shaped samples were taken from various parts of the potato it was noticed that the concentration of ascorbic acid was always higher in the bud end of the tuber than in the stem end. This variation led to the method of sampling previously described, that of taking four wedge-shaped samples from each potato analyzed: One each from the stem and the bud end, and one from each side.

Figure 2 shows the relationship between the ascorbic acid content of these various wedge-shaped sections of Green Mountain and Irish Cobbler potatoes during storage at 15.5° and 4.5° C. Each point on the curves represents the average of the values of from 5 to 10 tubers.

A similar distribution was present in the cooked potatoes both pared and unpared. This shows that there was little diffusion of the vitamin during cooking. The sharp rise shown in the curve for the bud end of Irish Cobblers stored at 15.5° C. occurred just before the removal of all of the sprouts and the abrupt decline immediately after this treatment. No analyses were made of the Green Mountain potatoes at this time.

With regard to the potatoes studied later, the immature Chippewas showed practically no difference in the distribution of ascorbic acid in the various sections, although there was a slight tendency toward a higher concentration in the bud end as they approached maturity. The new Green Mountain potatoes bought on the market showed only a slight tendency to have a higher concentration of ascorbic acid in the
Figure 2.—Distribution of ascorbic acid in potatoes stored at 15.5° and 4.5° C.: A, Green Mountain; B, Irish Cobbler.
bud end than in the stem end when purchased. This difference became very apparent by the end of the first week and increasingly more pronounced thereafter.

DISCUSSION OF RESULTS

The results of the present study indicate that the vitamin C value of potatoes is more dependent upon the time that elapses after harvesting before the potatoes are consumed and the temperature at which they are stored during that time than upon the method of preparation for consumption. The method of cooking most commonly employed, the boiling of pared potatoes, causes the greatest loss in ascorbic acid content, particularly since the cooking liquor is usually discarded. Losses due to other methods of cooking are somewhat smaller and fairly comparable. However, the decrease in the ascorbic acid content of potatoes during the first few weeks after harvesting exceeds even that which would be produced by the most destructive of the cooking methods.

Data presented here in regard to the effect of cooking upon the ascorbic acid content of potatoes is in general agreement with that of Scheunert, Reschke, and Kohlemann (22) and Wachholder, Heidinger, Grieben, and Köhler (26). The former reported the effect on the ascorbic acid content of steaming unpared potatoes and the latter that of steaming unpared potatoes and of boiling both unpared and pared potatoes. Much greater losses in ascorbic acid than were found here have also been reported, while some investigators have noted similar losses with some of the methods of cooking and gains with others. No such gains were found in the present investigation and no evidence was obtained in support of any of the theories advanced to explain these gains.

The apparent inconsistencies of the gains reported for ascorbic acid in cooked potatoes suggest the operation of an accidental factor. If, for example, boiling pared potatoes causes an apparent increase in ascorbic acid content, boiling unpared potatoes should have the same effect. However, if the type of distribution of ascorbic acid shown by Irish Cobbler potatoes at 15.5° C. were present but unrecognized, it is easy to see that the accidental selection of a disproportionately large number of samples from the bud end of the tubers would result in a relatively high ascorbic acid content as estimated from this group of samples. If, in addition, these samples represented cooked potatoes, the high value obtained would be thought to be a result of cooking rather than of sampling.

Another essential factor in the determination of the actual effect of a cooking method upon the ascorbic acid content of potatoes is the elimination of the effect of storage. This is particularly important when the potatoes are studied soon after being harvested since the rate of decrease in their ascorbic acid content is extremely rapid at this time. Unless determinations of the ascorbic acid content of both raw and cooked potatoes parallel each other in point of time, the result obtained for the effect of a cooking method may be very erroneous. In addition, the variation in ascorbic acid content from tuber to tuber is much greater soon after harvesting than it is after a period of storage. Consequently the sampling of an adequate number of tubers is imperative.
In sampling potatoes for the determination of their ascorbic acid content, all sections of the tuber were represented in proportion to their presence in the potato. The vitamin was completely extracted from raw potato tissue more easily than from the cooked tissue. Six successive extractions removed almost a constant percentage of the total ascorbic acid from the latter and a factor was employed to calculate the total.

There was no evidence of the presence in potatoes of a "bound" ascorbic acid insoluble in the extracting medium employed. No dehydroascorbic acid was found in the potatoes analyzed.

New Green Mountain potatoes were used in a comparison of the effects of boiling and "waterless" cooking upon the ascorbic acid content of potatoes. The variation in the ascorbic acid content from tuber to tuber in the new potatoes was so great that the losses obtained as a result of cooking these potatoes could not be regarded as significant.

Irish Cobbler potatoes stored at 15.5° C. were used to study the effect of pressure cooking, baking, boiling, and steaming upon the ascorbic acid content. Steaming and boiling unpared potatoes were the most conserving of vitamin C. Baking and pressure cooking caused slightly larger losses of ascorbic acid, while boiling pared potatoes was least conserving of the vitamin. However, the maximum loss of ascorbic acid due to a cooking method never exceeded 25 percent.

Chippewa potatoes decreased in ascorbic acid content during maturation. Because of the development of fusarium wilt during the growing period it was uncertain whether the effect shown was caused by maturity or disease.

All three varieties of potatoes lost ascorbic acid during storage. At 15.5° C. the losses were most rapid during the first few weeks of storage and became more gradual thereafter until, at the end of 26 weeks of storage, the ascorbic acid content had nearly reached a plateau value. Storage of a lot of Green Mountain and Irish Cobbler potatoes at 4.5° caused their ascorbic acid content to drop below that of a similar lot kept at 15.5°.

Ascorbic acid was not distributed uniformly throughout the tuber. Moreover the relative distribution of ascorbic acid differed in Green Mountain and Irish Cobbler potatoes. It was affected by the temperature at which the tubers were stored and was subject to continuous change during the period of storage.

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